California Environmental Protection Agency

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STANDARD OPERATING PROCEDURES

FOR

TELEDYNE/ADVANCED POLLUTION INSTRUMENTS (API) MODEL 400E OZONE ANALYZER

AQSB SOP 002

First Edition

MONITORING AND LABORATORY DIVISION

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California Environmental Protection Agency
AIR RESOURCES BOARD

Approval of Standard Operating Procedures (SOP)

Title: TELEDYNE/ADVANCED POLLUTION INSTRUMENTS (API) MODEL 400E OZONE ANALYZER

SOP: AQSB SOP 002, First Edition

Section: Operation Support Section

Branch: Air Quality Surveillance Branch (AQSB)

Division: Monitoring and Laboratory Division (MLD)

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1.0 GENERAL INFORMATION

1.1 Introduction:

This Standard Operating Procedure (SOP) describes procedures used by the California Air Resources Board (CARB) Air Quality Surveillance Branch (AQSB) to operate the Teledyne/Advanced Pollution Instruments Model 400E Ozone Analyzer (TAPI 400E) to measure ozone levels in ambient air. This procedure is designed to supplement the instruction manual by describing hardware or operating procedures as implemented by the AQSB. It is not the intent of this SOP to duplicate the instruction manual. A separate document is available for the analyzers acceptance test procedures.

1.2 Principle of Operation:

The API 400E is designed to accurately measure ambient ozone concentrations, despite the presence of interfering compounds. It detects ozone by measuring the absorbance of 254nm UV light emitted by a mercury vapor lamp and collected by a photomultiplier at the other end of the sample gas path. Using Beer-Lambert law, this UV absorbance can be correlated to the concentration of ozone and any other compound which may absorb UV light at this frequency.

$$A = \log_{10}\left(I_o / I\right)$$

Equation 1 - Beer-Lambert law where Io is the original intensity, I is the post sample gas intensity, and A is the absorbance.

In order to correct for interfering compounds, the API 400E calculates each value by taking the difference of two measurements and subtracting the difference.

$$A_{total} = A_i + A_{O3}$$

$$A_{O3} = A_{total} - A_i$$

Equation 2 - Total absorbance can be measured in the O3 meas. sample. Absorbance of the interfering compounds is measured in the O3 reference sample. The partial absorbance of the ozone is then calculated as the difference of the two. In the above equation, A_{total}, A_i, and A_{O3} stand for total, interfering compound, and ozone absorbance respectively.

For the first measurement, the UV light passes through a band-pass filter and through a glass tube which is filled with ambient air. The UV light absorbance is then measured by the photomultiplier located on the opposite side of the chamber. This initial measurement is commonly referred to as Ozone Measured (or “O3 Meas” on the front panel).

For the second measurement, sample air is scrubbed of all ozone and a resulting reference measurement is taken (or “O3 Ref”). The amount of UV radiation absorbed by ozone in the sample is then calculated as the difference of the actual absorbance during the O3 Meas and the scrubbed O3 Ref measurement cycles. For a more detailed discussion of the analyzer's measurement principle, please reference the manufacturer's instruction manual.

1.3 Safety Precautions:

Prior to cleaning the analyzer or performing any maintenance on the API 400E, place the MAIN power switch to the OFF position, and unplug the power cord. Avoid the use of chemical agents which might damage components.

Always use a three-prong, grounded plug on this analyzer. Adhere to general safety precautions when using compressed gas cylinders (e.g., secure cylinders, vent exhaust flows).

2.0 INSTALLATION PROCEDURE

2.1 General Information:

The API 400E is designed to be installed in an environmentally controlled environment. Normally the instrument should be rack mounted in a standard 19" instrument rack.

2.2 Physical Inspection:

The Model 400E is shipped with the following standard equipment

1. Power cord
2. Instruction manual
3. Side rails

Upon receiving the API Model 400E confirm that the instrument is in good working order and check for damage. If any damage is observed, contact your immediate supervisor. Prior to installation of the API 400E check the following:

1. Verify no apparent shipping damage
2. Check that all connectors are fully inserted
3. Check that all mechanical connections are tight

2.3 Instrument Siting:

The API 400E should be sited in accordance with the United States Environmental Protection Agency (U.S. EPA) Title 40, Code of Federal Regulations Part 53 and USEPA Designated Automated Equivalent Method EQOA-0992-087. See also the *Model 400E Ozone Analyzer Instruction Manual*, Section 2.2 “EPA Equivalency Designation” for a detailed list of EPA designation related siting requirements.

2.4 Data Logger Connection:

The API 400E has an eight-pin analog output connector strip on the rear panel. These lines are used to produce the voltage for the data logger. Pins 3 and 4 (A2) are the ozone concentration output for the data acquisition system. The pins are marked plus and minus and must be connected accordingly.

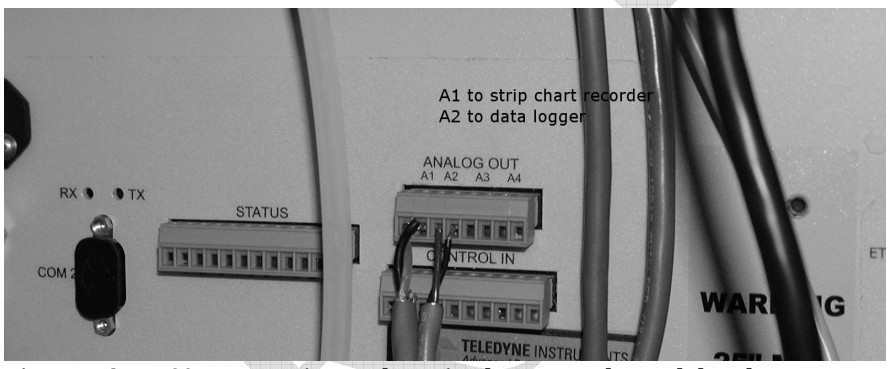

Figure 1 API 400E connection to the strip chart recorder and data logger.

2.5 Additional Data Logger Connections for the API 400E IZS:

In addition to producing the voltage for data logging purposes, the API 400E IZS model data loggers must be connected into ESC 8832, ESC8816, and ESC 8800 data loggers in such a manner that calibration cycles can be flagged (See Figure 2 and Figure 3 below).

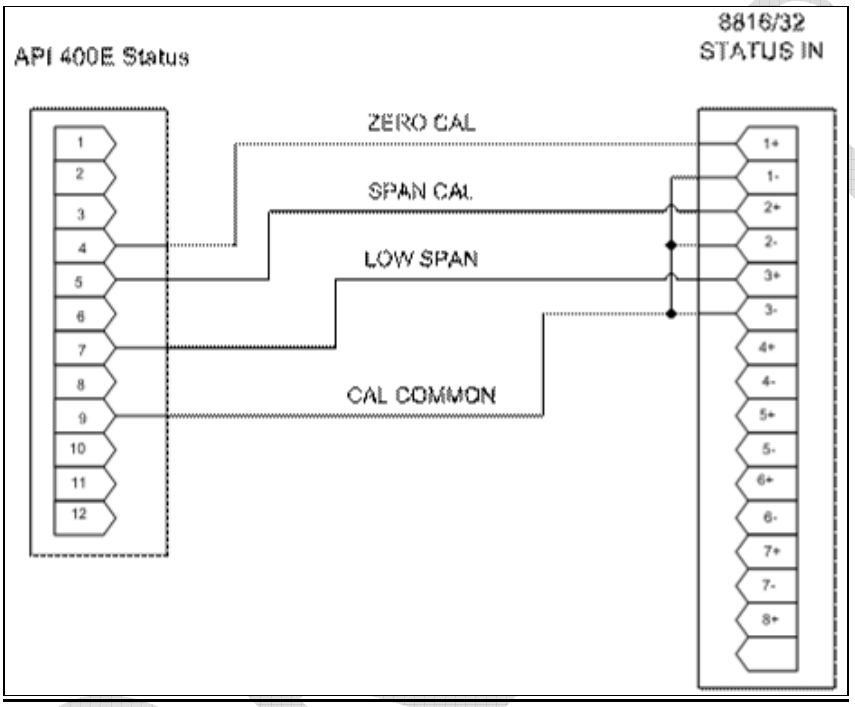

Figure 2 API400E IZS to ESC 8816 and 8832 data logger connections.

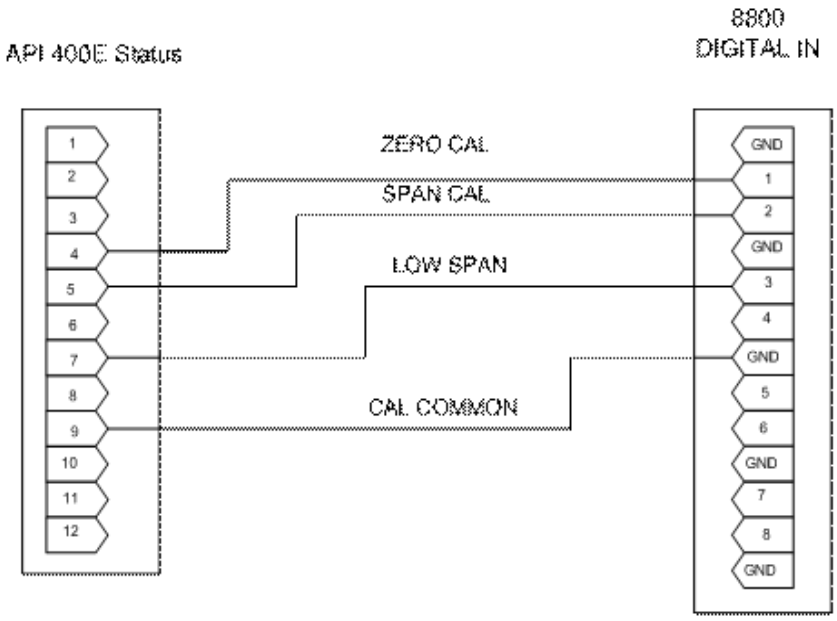

Figure 3 API400E IZS to the ESC 8800 data logger connection.

2.6 Strip Chart Connection:

The API 400E has an eight-pin output connector strip on the rear panel. The first two pins (A1) are the ozone concentration output for chart recorder. The pins are marked plus and minus and must be connected accordingly (see Figure 1).

2.7 Operation Verification:

NOTE: Prior to operation of the API Model 400E analyzer, operators must read the instrument manual to familiarize themselves with the operation of the instrument.

Prior to operating the API 400 E, ensure that the proper connections have been made. In summary, at most ARB monitoring locations, this involves the following connections:

- Connect the sample inlet line from the manifold to the sample port on the rear panel.
- Connect the pump exhaust to a suitable vent outside the analyzer area.
- Connect IZS inlet input (if installed) to a clean, dry air supply.
- Connect power cord to an appropriate power outlet.
- Connect recording devices to the terminal strip on the rear panel reference sections 2.4 and 2.5 of this document.

After proper connections have been made, turn on the power switch located on the lower right corner of the front panel. The display will show a single dash on the left side of the screen for approximately 30 seconds. Subsequently, a boot progress meter will be displayed showing the percent completion of loading the operating system.

The system should automatically enter into sample mode after reboot. The display will now show “SYSTEM RESET” at the top of the screen, the green sample LED on the front of the panel should be on, the red LED should be flashing, and the word “SAMPLE” should flash in the upper right hand of the display until the warm-up cycle is complete.

Allow approximately one hour for the analyzer to stabilize. Preview all diagnostic values by repeatedly depressing the first [<TST] or second [TST>] command keys on the front of the instrument.

Figure 4 Front panel of the API 400 E.

Compare these values to those listed on the factory final checkout sheet in the instrument manual or those listed on the Operation Support Sections Instrument Laboratory Data Sheet. Verify that the test parameters are within the limits prescribed by Table 1, API 400E Standard Configuration Table.

3.0 CONFIGURATION

3.1 Instrument Configuration

The API 400E is usually configured by the ARB's Operation Support Sections Instrument Laboratory and requires no field configuration. However, field staff are strongly encouraged to verify that their instrument is properly configured.

TEST PARAMETER	NOMINAL	RANGE
Time	Current PST time	+/- 2 minutes
Range (ppb)	500	0 to 1000
Stabil (Standard Deviation of O3 Readings)	0.1 – 0.3	< 1 w. zero air
O3 Meas (Current V/F conv MV, measured channel)	4000	3500 to 4500
O3 Ref (Current V/F conv MV, reference channel)	4000	3500 to 4500
O3 Gen (IZS ref channel feedback)	+/- 10% demand	80-5000 MV
O3 Drive (Drive voltage for O3 Gen Lamp)	+/- 10% demand	0-5000 MV
Pressure (Absolute Pressure, inHg)	Ambient Press.	29 to 31
Sample Fl (Sample Flow through Analyzer, c/min)	800	800 +/- 80
Sample Temp (°C)	Ambient Temp	Ambient +/- 10°
Photo LMP (Photometer Lamp Housing Temp, °C)	58 C	58 +/- 2
O3 Gen Temp (O3 Generator Housing Temp, °C)	48 C	+/- 1°
Box Temp (Internal Box Temp, °C)	Ambient Temp	Ambient +/- 10°
Slope (Internal Formula, Slope)	1.00	0.9 to 1.1
Offset (Internal Formula, Offset)	0.0	-5.0 to 5.0

Table 1 Standard AQSB API 400E Configuration Table

3.2 Datalogger Configuration

Datalogger channel configuration for the API 400E is covered in the AQSB SOP for the datalogger model you are using. The datalogger channel (channel one) for the ozone analyzer must be configured for a 0 to 1 volt signal equaling 0 to 500 PPB assuming the range of the API 400E is set to 500 ppb.

3.3 Strip Chart Recorder Configuration

Strip chart channel configuration for the API 400E is covered in the AQSB SOP 604. The strip chart channel (channel one) for the ozone analyzer must be configured for a 0 to +1 voltage output range, with units from 0 – 500 ppb. The strip chart recorder color should be set to light green.

4.0 CALIBRATION INFORMATION

4.1 Calibration Introduction:

A calibration is a procedure for aligning or checking the output of an instrument to a known "true" standard. To ensure the quality of the data provided by the API 400E, the analyzer must be calibrated prior to use, after any major maintenance, and after every six months of use.

AQSB utilizes two forms of "calibration", nominally referred to as "AS-IS" and "Final" calibrations. An "AS-IS" calibration is performed initially to asses the instruments accuracy. The "AS-IS" calibration verifies the accuracy of the recently generated data; usually back to the previous calibration. A "Final" calibration is performed after an instrument has been aligned to a "true" standard. Typically an "AS-IS" calibration is performed to determine if the instrument warrants further maintenance. If it does then an alignment, followed by a "Final" calibration is performed. This section of the SOP provides a list of the necessary equipment and the correct procedures to accurately calibrate the analyzer.

4.2 Calibration Overview:

Test concentrations for ozone must be obtained in accordance with UV photometric calibration procedures listed in 40 CFR 50 Appendix D (Measurement Principle and Calibration Procedure for the Measurement of Ozone in the Atmosphere) or by means of a certified ozone transfer standard. The transfer standard must be traceable to a primary ultraviolet photometer and recertified on a quarterly basis.

The test concentration for ozone generated using an ozone transfer standard should be delivered directly to the API 400E via the inline particulate filter "hockey puck".

4.3 Calibration Apparatus for the API 400E:

1. Certified Ozone/Gas Transfer Standard.
2. One-quarter inch Teflon tubing for air flow connections.
3. Zero air supply
4. Calibrated laminar flow device for measuring air flow (mass flow meter).
5. Calibration report forms.
6. Simulated calibration line if using calibrator for ozone source.

5.0 CALIBRATION PROCEDURES

Prior to calibration, verify the operation of the transducers in the analyzer by recording the values of temperature and pressure from the analyzer and from a certified transfer standard for one point.

5.1 Calibration at Altitude

Calibrating the API 400E analyzer at altitude requires no special adjustments because the analyzer compensates for changes in temperature and pressure

NOTE: The data acquisition system (DAS) is used for primary data recording, therefore the DAS data reading should be used for calibration calculations in lieu of the analyzer display readings.

5.2 AS-IS Calibration:

AS-IS instrument calibrations should be made prior to making any analyzer repairs or adjustments. The ozone scrubber and solenoid valve should not be replaced without first performing an AS-IS calibration. It is acceptable to perform routine service checks prior to an AS-IS calibration. Prior to beginning AS-IS calibration "mark down" the appropriate DAS channels on the station datalogger.

1. When setting up the certified ozone/gas transfer standard to generate the test concentrations for ozone, configure the transfer standard so that the ozone generated is measured by the transfer standards UV photometer. Using one-quarter inch (1/4" O.D.) Teflon tube, connect a zero air source and exhaust lines to the transfer standard. Connect a 1/4" O.D. Teflon line from the transfer standard's sample port to the API 400E "hockey puck".

   Energize the zero air system and configure the transfer standard so that zero air is flowing through the calibration assembly.

2. Allow both the transfer standard and the analyzer being calibrated to warm-up for at least one hour. All instrument covers should be on during the calibration, as the calibration is dependent upon the internal temperature of the analyzer. The transfer standard diagnostic values should be stable; showing no upward or downward trend when operating temperature has been reached.

3. Record the station information, analyzer identification numbers, analyzer settings, calibration equipment information and any other pertinent information on the calibration data sheet (Appendix B).

4. Obtain the instrument internal slope and offset from the API 400E front display following the steps in the instruction manual. Record the AS-IS slope and offset on the calibration data sheet. Confirm that the values are the same as at the end of the previous calibration. If not, investigate when and why these values have changed before beginning calibration.

5. Adjust the sample air flow rate of the transfer standard to approximately 5.0 SLPM as calculated from the transfer flow standard reading and the transfer flow standard certificate values. Measure and record the AS-IS sample air flow rate of the API 400E. Connect an 18 inch long Teflon line (1/4" O.D.) to the vent port of the transfer standard and measure the vent flow. The vent flow should be greater than 0.5 LPM.

6. Allow the analyzer and transfer standard to sample zero air. When a stable zero reading is reached (0 ± 3 ppb) and the API 400 E stability test function (a measure of the standard deviation taken from the last ten data points) is less than 1 ppb, record 3 consecutive DAS display values, recorded approximately one minute apart, with the respective columns labeled "pre-zero" on the calibration data sheet. Record the average strip chart and API 400E zero reading in the space provided.

7. Set the transfer standard to produce a Span ozone concentration of approximately 80% of full scale (400 ppb) of the analyzer being calibrated as read by the transfer standard.

8. When the stability test function is less than 1 ppb, record ten consecutive digital values in the columns labeled "1st pt" for each analyzer. Calculate the sum and average of the ten numbers and record the value on the calibration data sheet in the appropriate blocks. Record the average strip chart recorder and API 400E span readings in the appropriate space.

9. Record data for the "2nd Pt", "3rd Pt", and “4th Pt": after adjusting the ozone transfer standard output to approximately 0.25, 0.090, and 0.05 PPM, respectively and stability readings are less than 1 ppb. Calculate and record the sum and average readings.

10. Repeat step 6 and record the value on the column marked "post- zero". Average the "pre-zero" and "post-zero" readings and use this value as the zero correction.

11. Calculate corrected averages for the transfer standard analyzer using the formula:

Corrected Average (Transfer Standard) = (Average Reading - Zero Correction) x True Ozone Correction Factor

12. Calculate the summation of corrected averages for the transfer standard (S1) by adding the corrected averages for points 1, 2, 3, and 4.

13. Calculate the corrected averages of the analyzer being calibrated using the formula:

    Corrected Average = Average Reading - Zero Correction

14. These values, in PPM, should correspond to the analyzer's DAS display. If not, check the calibration of the recording device before making adjustments to the analyzer.

15. Calculate the summation of corrected averages for the analyzer being calibrated (S2) by adding the corrected averages for points 1, 2, 3, and 4.

16. Calculate the average percent difference from true ozone:

$$Overall\%\,Accuracy = \left(\frac{S2 - S1}{S1}\right) * 100$$

    If the percent difference is more than $\pm$ 3% or 3 ppb (whichever is greater), or if the ozone scrubber is replaced, the analyzer must undergo a final calibration.

17. Using a best fit linear regression, calculate the slope (m) and intercept (b) equation of the calibration line:

    Where x = true concentration, in PPM
    y = analyzer response, in PPM

18. Calculate the percent change from the previous calibration:

    Percent change from the previous calibration =
    New Slope - Old Slope x 100 Old Slope

19. Record the calibration data on the Calibration Report (See References).

5.3 Final Calibration:

Perform the final calibration as follows:

1. Challenge the API 400E with zero air until the reading stabilizes (not more than +/-2% over a 5 minute time period).

   NOTE: IF THE ANALYZER FAILS TO STABILIZE WHILE SAMPLING ZERO AIR AT, IT WILL BE IMPOSSIBLE TO ENTER ZERO AND IT WILL BE NECESSARY TO REFER TO THE TROUBLESHOOTING SECTION OF THE INSTRUMENT MANUAL.

2. Perform a zero alignment on the API 400E by following the steps in the instrument manual section 3.3.2 “Perform the Zero/Span Calibration Procedure”. The API 400E should now be zeroed, but the blinking cal light indicates that data is not being sent out. This status will last for approximately 5 minutes.

3. Challenge the API 400E with a span level of ozone. This level should be approximately 80% of full scale (400 ppb) as measured by the UV photometer. Allow the API 400E to sample until a stable reading is achieved.

4. When the span level is stable, SPAN the API 400E by performing the steps in the instrument manual section 3.3.2, “Dynamic zero/span adjustment” of the instruction manual.

5. Obtain the instrument internal slope and offset from the API front display following the steps in the instruction manual. Record the final slope and offset on the Calibration Data Sheet (See References).

6. Return to Section 5.2 of this document, step 6 to complete the remaining steps of the final calibration. If the analyzer cannot be properly calibrated, refer to the API Instruction Manual for assistance in troubleshooting and repairing the analyzer.

5.4 Internal Zero Span (IZS) Calibration:

The IZS calibration is used to adjust the internal ozone generator to match its photometer value. The M400E measures the IZS reference signal and ozone concentration at five different lamp voltages. During the calibration process the screen will display the percent completed, taking approximately 50 minutes to complete.

AQSB standard configuration indicates that the low span should be set for 90 PPB and the high span should be set for 400 ppb. Refer to the API 400E manual, section 7.4 “Manual Zero / Span (IZS) Calibration With Zero/Span Valve Option Installed” to set the IZS calibration parameters. Also, ensure that units running the IZS feedback option have their feedback mode set to *Ref*. If the IZS ozone concentration displays some fixed value higher or lower than 90 and 400, you may adjust these settings until the resulting display matches the targeted value.

At a minimum the IZS calibration should be performed following a change or rebuild of the sample pump, adjustment of the flow rate, replacement of the ozone lamp, or after conducting an as-is or final calibration.

1. From the front panel of the instrument, choose *setup*, *more*, followed by *diag*.
2. Ensure that the password reads *818,* and choose *enter*.
3. Choose the *next* entry until obtaining the *ozone generator calibrator* menu item.
4. Choose enter and wait for approximately fifty minutes. After completion, choose *exit* several times until arriving back at the main menu.

Immediately following the IZS calibration, record the average of the next three auto IZS calibration sequences to determine the new baseline for zero, precision, and span values. These will become the new source values for use in AQDAS II.

5.5 Automatic Zero/Span Check:

The API 400E with IZS option is capable of conducting automatic calibrations on regular intervals. After conducting IZS calibration, daily calibration checks should be scheduled. Detailed procedures can be found in the Instruction Manual, section 7.6 “Automatic Zero/Span Check With Zero/Span Valve Options Installed”.

AQSB standard configuration uses the parameters detailed in the following table:

Parameter	Value
Mode	Zero-Lo-Hi
Starting Date	The day following the IZS calibration.
Starting Time	0350 Hours
Delta Days	1
Delta Time	0
Duration	20

Table 2 API 400E IZS configuration parameters

6.0 ROUTINE SERVICE CHECKS

6.1 General Information:

The following routine service checks are to be performed in accordance with the maintenance schedule (Table 3). Perform the routine service checks at least at the prescribed intervals or more often in necessary. The AQSB Monthly Quality Control Check Sheet (See References) should be completed weekly and submitted monthly to the station operator's supervisor. The station operator must keep a copy of the Monthly Quality Control Check Sheet in the air monitoring station. Detailed routine maintenance procedures can be found in Chapter 11 of the instruction manual.

	Value	Daily	Weekly	Monthly	Semi-Annual	As Req
Power On	On	X				
Error Flags	None	X				
Check Chart Recorder	None	X				
Record Test Parameters	Record		X			
Change Inlet filter	Clean		X			
Complete AQSB QC Form	None			X		
Perform field calibration	6 months				X	
Adjust photo lamp	< 2500 mV					X
IZS Calibration	None					X

Table 3 Maintenance Schedule

6.2 Daily Checks:

Review instrument data and check chart recorders for any indication of analyzer malfunction. Check instrument front panel for any error messages.

6.3 Weekly Checks:

Record test parameters on the AQSB QC Form 002 (API 400E) check sheet. Change the inline particulate filter.

6.4 Monthly Checks:

Complete the AQSB QC Form 002 (API 400E) and submit it to your immediate

supervisor along with station data.

6.5 As Required Checks:

Clean optical chamber and adjust photo lamp when O3 reference value is less than 2500 mV. Complete an IZS calibration upon completion of instrument calibrations, flow adjustments, or lamp replacements.

6.6 Semiannual Checks:

Perform instrument calibration.

7.0 MAINTENANCE AND PROCEDURES

7.1 General Information:

The API 400E is designed to operate unattended for long periods of time and, other than the routine checks required in section 6.0 of this SOP, require little maintenance. However, maintenance requirements may vary from instrument to instrument, thus operators should refer to the instrument operating manual to become familiar with maintenance requirements.

If station operators cannot repair an instrument using procedures stated in the instrument manual, contact the Operations Support Sections Instrument Laboratory.

8.0 TROUBLESHOOTING

8.1 General Information:

The API 400E has been designed to rapidly detect possible problems and allow for their quick evaluation and repair. During operation, the analyzer continuously performs self-test diagnostics and provides the ability to monitor the key operating parameters of the instrument without disturbing monitoring operations.

Should instrument malfunctions occur and troubleshooting is required to determine the problem, operators should refer to Chapter 11, “Troubleshooting and Repair Procedures” in the API instrument manual.

REFERENCES

- AQSB QC Form 002 (API 400E) Check Sheet
  http://arb.ca.gov/airwebmanual/amwmn.php?c=0
- AQSB Cal Form 002 (API 400 E) Calibration Sheet
  http://arb.ca.gov/airwebmanual/amwmn.php?c=0